Name _____Period _____

Molar Mass of Dry Ice

Your Tasks (Mark these off as you go)

- ☐ Define key vocabulary
- ☐ Review the ideal gas law
- ☐ Calculate the molar mass of a gas
- ☐ Write a procedure to determine the molar mass of dry ice
- ☐ Collect the data necessary to determine the molar mass of dry ice
- ☐ Calculate the experimental molar mass of dry ice
- ☐ Interpret your results
- ☐ Receive credit for this lab

☐ Define key vocabulary

Dry ice

Sublimation

Avogadro's law

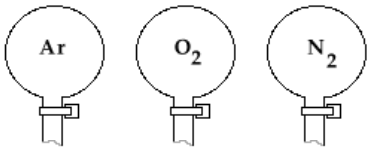
Ideal gas law

Ideal gas constant

Molar mass

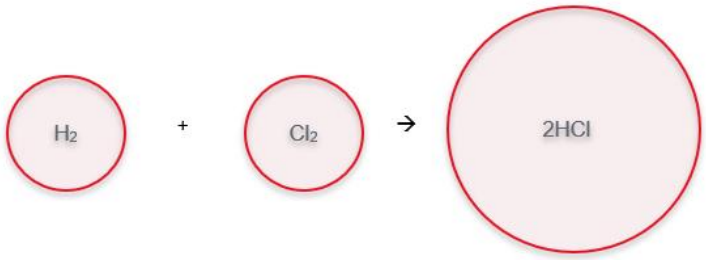
☐ Review the ideal gas law

As gas is added to a balloon, its volume expands – this is true regardless of the identity of the gas. This fact led Avogadro to propose the following law*: Equal volumes of gases at the same temperature and pressure contain equal numbers of molecules or moles*. This concept is illustrated below,

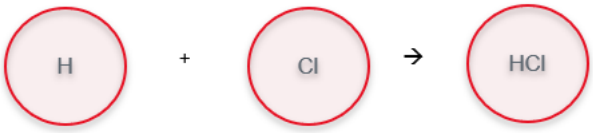


Volume:	22.4 L	22.4 L	22.4 L
Mass:	40 g	32 g	28 g
Quantity:	1 mol	1 mol	1 mol
Pressure:	1 atm	1 atm	1 atm
Temperature:	273 K	273 K	273 K

Avogadro's law was an important milestone as it enabled scientist to utilize gas phase reactions as a way to determine the formulas for different molecules. For example, consider the reaction between hydrogen gas (H_2) and chlorine gas (Cl_2). In the reaction shown below, 1 volume of H_2 and 1 volume of Cl_2 makes 2 volumes of HCl. This relationship led scientists to conclude that both H_2 and Cl_2 are diatomic molecules.



If H_2 and Cl_2 were NOT diatomic molecules, the following would occur instead,



In the gas phase reaction between two unknown gases to produce AB, the following data was collected. Based on the data, what are the formulas for A and B?

1 volume A	1 volume B	2 volumes AB
2 volumes A	2 volumes B	4 volumes AB
1 volume A	2 volumes B	2 volumes AB
2 volumes A	1 volumes B	2 volumes AB

In the gas phase reaction between two unknown gases to produce A_2C, the following data was collected. Based on the data, what are the formulas for A and C?

1 volume A	1 volume C	1 volume A_2C
2 volumes A	1 volumes C	2 volumes A_2C
2 volume A	4 volumes C	2 volumes A_2C
1 volumes A	2 volumes C	1 volumes A_2C

Combining Boyle's law, Charles's law, Gay-lussac's law, and Avogadro's law into a single expression gives a general equation which relates the four measurable quantities: pressure, volume, temperature, and moles of a gas. This general equation, also called the ideal gas law, can be used to calculate information about any gas sample,

PV = nRT

In the above equation, P is pressure in atmospheres, V is volume in liters, n is moles, and T is temperature in Kelvin. R is called the ideal gas constant and has the value 0.0821 $\frac{\text{atm} \cdot \text{L}}{mol \cdot K}$. An example of how to use the ideal gas law is illustrated below,

Example

What is the pressure in atmospheres exerted by a 0.500 mol sample of nitrogen in a 10.0 L container at 298K

Solution

Given: V = 10.0 L; n = 0.500 mol; T = 298 K
Unknown: P

Substituting and solving,

PV = nRT

$$P = \frac{nRT}{V} = \frac{(0.500mol)(0.0821\frac{atm \cdot L}{mol \cdot K})(298)}{10.0L} = 1.22atm$$

What is the volume in liters of 2.00 mol of CO_2 gas at a STP. (Recall STP stands for Standard Temperature and Pressure. That is where P = 1 atm and T = 273 K)

Carbon dioxide sublimes under normal atmospheric conditions. If student collected 750 mL of carbon dioxide gas at 25°C and 755 atm, how much carbon dioxide, in moles, did the student collect?

□ Calculate the molar mass of a gas

Recall that molar mass can be expressed as the ratio between the mass and the moles

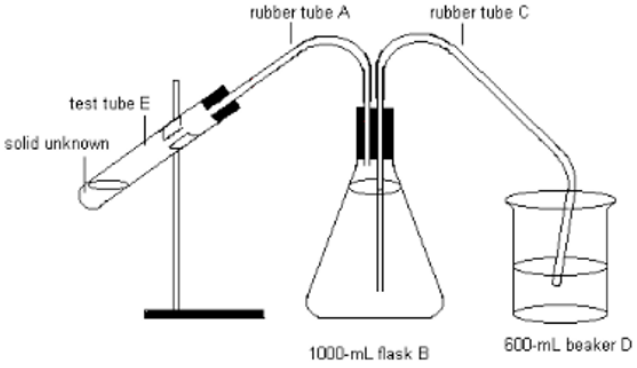
$$Molar\ Mass = \frac{Mass(g)}{moles}$$

From the above equation we can see that the molar mass of a gas can be calculated if we know both the mass of the gas and the moles.

Carbon dioxide gas was generated by the sublimation of dry ice. The mass of the test tube and contents at the beginning of the experiment was 23.00 g. The mass of the test tube and contents after sublimation was 22.75. The volume of carbon dioxide collected at 24°C and atmospheric pressure of 762 mm Hg was 128 mL. (a) Calculate the mass of carbon dioxide gas produced (b) Calculate the moles of carbon dioxide gas produced (c) Calculate the experimental molar mass of the carbon dioxide gas

☐ Write a procedure to determine the molar mass of dry ice

Watch the demonstration on how to collect carbon dioxide gas using the apparatus shown below. Then work with your group to develop a procedure to collect all the data necessary to determine the molar mass of dry ice. Your procedure must be written in such a way so that another chemistry student at Timberline HS could perform the experiment and obtain similar results.



Before you continue have Ms. Pluska approve your procedure.

☐ Collect the data necessary to determine the molar mass of dry ice

- Test out the procedure you wrote above with a trial run. If you are satisfied with your procedure, you may continue, if not, go back and revise it.
- Run your experiment three times. This will ensure you have sufficient data to calculate the average experimental molar mass of dry ice. Record all your data in the table below.

Data table

Trial	Mass of dry ice + test tube before	Mass of dry ice + test tube after	Volume of water collected
1			
2			
3			
Atmospheric pressure			
Temperature of water			

Observations

□ Determine the experimental molar mass of dry ice

Before you can calculate the molar mass, you must make sure each of the variables you recorded are in the proper units. For each trial (1) Calculate the mass of CO_2 that sublimed (2) Convert the temperature in Celsius to Kelvin (3) Convert the volume of water collected to liters (4) Convert the atmospheric pressure to atmospheres. Record these new values in the table below.

Trial	Mass of CO_2 the sublimed	Temperature in Kelvin	Volume of water in Liters	Pressure in atmospheres
1				
2				
3				

For each trail calculate the moles of carbon dioxide you collected using the ideal gas equation, PV = nRT. Recall that the value of R is 0.0821.

Trial	Moles (n)
1	
2	
3	

For each trail calculate the experimental molar mass of dry ice.

$$Molar\ Mass = \frac{Mass\ of\ dry\ ice\ that\ sublimed(g)}{moles\ of\ carbon\ dioxide\ collected}$$

Trial	Molar Mass (g/moles)
1	
2	
3	

Calculate the average molar mass of dry ice based on your three trials.

Calculate the actual molar mass of carbon dioxide given the values of carbon and oxygen on the periodic table.

Calculate the percent error associated with your average molar mass obtained from your experiment.

$$percent\ error = \frac{actual\ value - experimental\ value}{actual\ value}\ x\ 100$$

☐ Interpret your results

Answer the following in complete sentences. You must also be mindful of spelling, punctuation and overall writing quality.

What was the purpose of this experiment?

In your own words, summarize what you did to accomplish the purpose.

Summarize your findings along with the percent error associated with your results. In your summary you must include values you obtained.

Consider the gases below. If you conducted the same experiment with these gases, how would your results compare? Would the percent error be about the same, less, or more?

Gas	Percent error same, less, or more
N_2	
SF_6	
H_2	
Propane (C_3H_8)	

Indicate the effects of the following errors on the experimental value you obtained for the molar mass of dry ice.

Error	Major/Minor	Effect on the obtained value
Carbon dioxide is soluble in Water		
Condensation on the outside of the test tube		

□ Receive Credit for this lab

Each group member must complete and submit their own lab to receive credit